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Effect of the "Long Term Solution" seat pack on Harvard II (CT156) aircrew accommodation

Pierre Meunier

Defence R&D Canada – Toronto
Technical Report
DRDC Toronto TR 2002-172
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Canada

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This study, approved by the DRDC Toronto Human Research Ethics Committee, was conducted in conformity with the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans.

Abstract

The requirement to include additional survival equipment as part of the seat survival kit of the Harvard II has caused a significant increase to the seat thickness (4 to 5 cm). A previous study determined that any increase in seat thickness would likely have repercussions on the ability of the taller individuals to see all of the information displayed by the Electronic Attitude Director Indicator (EADI), on control stick authority, and possibly on helmet to canopy clearance. The object of this study was to assess the impact of this new seat pack, or Long Term Solution (LTS) seat pack, on pilot accommodation. The study found that approximately 12% to 17% of student pilots (i.e. individuals in the front seat) would not be able to see all of the EADI information. In addition, the taller 2% to 3% of pilots would likely exceed the aircraft's maximum sitting height limits and have insufficient clearance between the top of the helmet and the canopy. Stick authority was relatively little affected by the proposed seat compared to the baseline. Removal of the g-suit from the winter clothing configuration significantly improved stick authority.

Résumé

L'obligation d'inclure du matériel de survie additionnel dans le nécessaire de survie du siège du Harvard II a entraîné une importante augmentation de l'épaisseur dudit siège (de 4 à 5 cm). Une précédente étude avait établi que toute augmentation de l'épaisseur du siège risquait d'avoir des répercussions sur la capacité des personnes de grande taille à voir l'intégralité de l'information affichée par l'indicateur-directeur d'assiette électronique (EADI), sur leur maîtrise du manche, voire même sur l'espacement qui sépare le casque de la verrière. La présente étude avait pour objet d'évaluer les répercussions que pouvait avoir ce nouveau paquetage de siège, appelé solution à long terme (LST), sur la posture du pilote. Cette étude a établi que de 12 à 17 % des élèves-pilotes (c'est-à-dire des personnes se trouvant sur le siège avant) ne pourraient pas voir l'intégralité de l'information affichée par l'EADI. De plus, les pilotes les plus grands (2 à 3 %) risquent fort de dépasser la hauteur assise maximale admise dans l'appareil et de ne pas jouir d'un espace suffisant entre le sommet du casque et la verrière. La maîtrise du manche s'est révélée être relativement peu affectée par le remplacement du siège d'origine par le siège proposé. La suppression de la tenue anti-g de la tenue d'hiver a amélioré considérablement la maîtrise du manche.

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Executive summary

The requirement to include additional survival equipment as part of the seat survival kit of the Harvard II has caused a significant increase to the seat thickness of 4 to 5 cm. A previous study determined that any increase in seat thickness would likely have repercussions on the ability of the taller individuals to see all of the information displayed by the Electronic Attitude Director Indicator (EADI), on control stick authority, and possibly on helmet to canopy clearance. The object of this study was to assess the impact of this new seat pack, or Long Term Solution (LTS) seat pack, on pilot accommodation.

Eleven subjects were recruited from the pool of students and instructors present at the NATO Flying Training in Canada (NFTC) training facility in Moose Jaw, Saskatchewan. Although mainly tall seated-height individuals were required to assess the impact of the seat pack change, a broad range of individuals was selected for completeness. Subjects were selected around a 95% probability ellipse of stature and weight, which are general indicators of lengths and circumferences.

The study found that the front cockpit is more limiting than the rear cockpit and that approximately 12% to 17% of student pilots in that seat would not be able to see all of the EADI information (defined as the top of the yellow triangle), depending on whether summer or winter clothing is worn. The baseline study done with the original seat estimated that virtually all Canadian Forces pilots (>99%) would see all of the EADI information.

Although a technical solution to the EADI visibility problem may be devised, i.e. by relocating the enunciator panel, this may allow individuals to sit much higher than the reference eye point and bring pilots closer to the maximum sitting height limit. An estimated 2% to 3% of pilots may exceed this limit and therefore have insufficient clearance between the top of their helmet and the canopy.

Stick authority did not appear to be affected much by the higher seat position compared to the slightly lower "minimum over the nose" seat position, at least when summer clothing is worn. On the positive side, removal of the g-suit from the winter clothing condition offered significant improvements in stick range of motion.

Meunier, P, 2002. Effect of the "Long Term Solution" seat pack on Harvard II (CT156) aircrew accommodation. DRDC Toronto TR 2002-172. DRDC Toronto.

Sommaire

L'obligation d'inclure du matériel de survie additionnel dans le nécessaire de survie du siège du Harvard II a entraîné une importante augmentation de l'épaisseur dudit siège (de 4 à 5 cm). Une précédente étude avait établi que toute augmentation de l'épaisseur du siège risquait d'avoir des répercussions sur la capacité des personnes de grande taille à voir l'intégralité de l'information affichée par l'indicateur-directeur d'assiette électronique (EADI), sur leur maîtrise du manche, voire même sur l'espacement séparant le casque de la verrière. La présente étude avait pour objet d'évaluer les répercussions que pouvait avoir ce nouveau paquetage de siège, appelé solution à long terme (LST), sur la posture du pilote. Onze sujets ont été recrutés parmi les élèves et les instructeurs présents au centre de formation du NFTC de Moose Jaw (Saskatchewan). Bien qu'on ait principalement recherché des sujets de grande taille assise pour évaluer les répercussions du changement de paquetage de siège, un échantillon d'individus plus large a été sélectionné par souci d'exhaustivité. On a choisi des sujets dont la taille et le poids s'encadraient dans une ellipse de probabilité de 95 %, qui donne en général une indication de la longueur et de la circonférence.

L'étude a révélé que le poste de pilotage avant était le plus contraignant des deux et qu'environ 12 à 17 % des élèves-pilotes ne pourraient y voir l'intégralité de l'information affichée par l'EADI (définie comme le sommet du triangle jaune), selon qu'ils portaient leur tenue d'été ou d'hiver. L'étude de référence entreprise avec le siège d'origine avait établi que quasiment tous les pilotes des FC (> 99 %) seraient capables de voir l'intégralité de l'information affichée par l'EADI.

Bien qu'il soit possible de trouver une solution technique au problème de visibilité de l'EADI, en déplaçant par exemple le panneau de contrôle, le fait de permettre aux pilotes de s'asseoir plus haut que le point de référence visuelle les rapprochera de la limite maximale de hauteur assise. On estime que 2 à 3 % des pilotes risquent de dépasser cette limite avec un espacement insuffisant entre le sommet de leur casque et la verrière.

La maîtrise du manche ne semble pas être affectée par une posture assise plus haute lorsqu'on compare cette dernière à la position assise « juste au-dessus du nez » plus basse, du moins lorsque le pilote porte la tenue d'été. Fait à noter, la suppression de la combinaison anti-g de la tenue d'hiver permet par ailleurs une amélioration significative de la plage de déplacement du manche.

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Acknowledgements

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1. Introduction

The DND has tasked Bombardier Aerospace to study the feasibility of expanding the current survival aids container to include a number of additional items including, but not limited to, a life raft and a –30C sleeping bag. This caused Martin-Baker to make the seat thicker (by up to 50 mm) and make changes to the sitting platform, seat backrest, seat bucket actuator, seat firing handle, lap straps, Seat Survival Kit (SSK) fitting straps and cushions (Jonas, 2002). These modifications would cause subjects requiring the seat full down to sit that much higher in the cockpit.

The original cockpit accommodation study (Meunier, 2001) found that the Harvard II would accommodate all but the top 0.5% of males in seated height in the front seat, due to their inability to obtain full view of the information displayed on the Electronic Attitude Director Indicator (EADI). Any increase in seat pack thickness would therefore reduce the percentage of student pilots accommodated. The purpose of this study, which was sponsored by the Directorate of Technical Airworthiness (DTA), was to determine the extent to which tall subjects would be affected by the proposed increase in seat pack thickness. Since stick authority is governed partially by seat height (Meunier, 2001), a secondary objective of this study was to determine whether stick range of motion was affected by the LTS seat.

This report is the result of the cockpit accommodation evaluation performed on the Harvard II (tail number 156109) on the week of August 12th 2002, at the NFTC training centre in Moose Jaw, and deals strictly with anthropometric issues related to the impact of the seat change on EADI visibility and stick authority.

2. Method

2.1 Subjects

Eleven subjects were recruited from the pool of students and instructors present at the NFTC training facility in Moose Jaw, Saskatchewan. Although mainly tall seated-height individuals were required to assess the impact of the seat pack change, other parts of the study conducted by the Aerospace Engineering Test Establishment (AETE) required a broader cross-section of individuals. The anthropometric characteristics of the students and instructors on strength in Moose Jaw were gleaned from the database of their measurements kept at Central Medical Board (CMB) at DRDC-Toronto. Stature and weight, which are general indicators of lengths and circumferences, were picked as selection variables. The sampling strategy, which is illustrated in Figure 1, consisted in selecting subjects around a 95% probability ellipse.

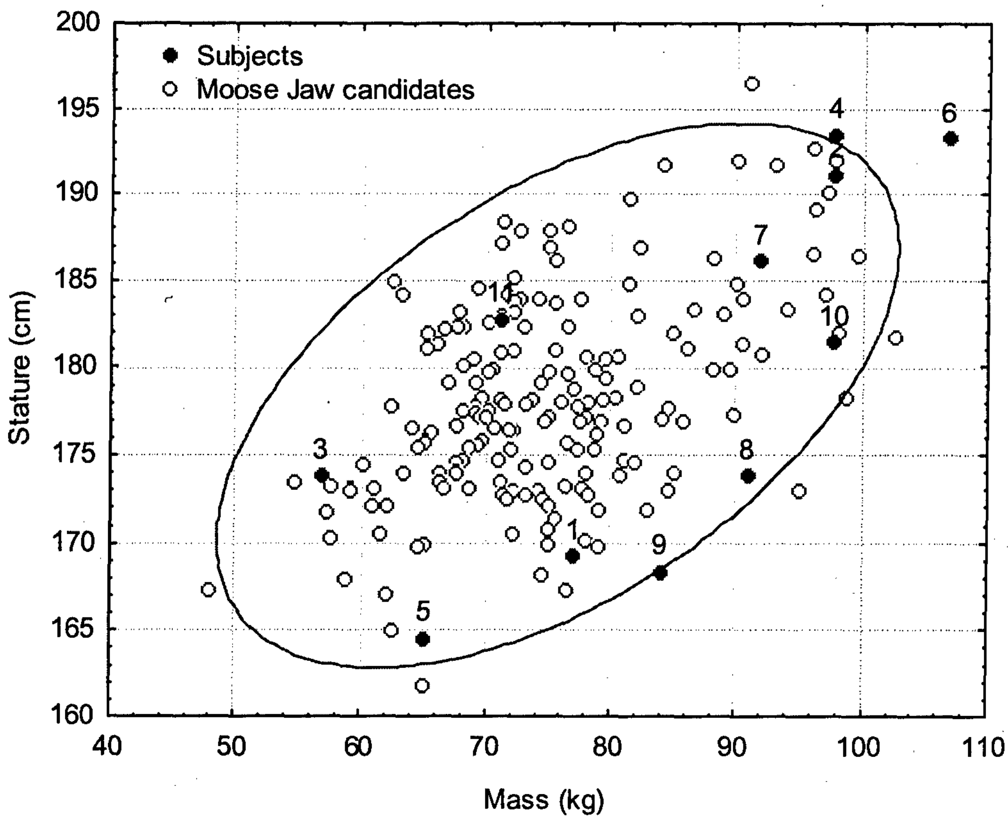

Figure 1. *Test subjects relative to pool of students and instructors in Moose Jaw.*

2.2 Test protocol

The following anthropometric measurements were made for each participant (see Appendix A for data):

- Stature
- Sitting height
- Eye height sitting
- Acromial height sitting
- Knee height sitting
- Buttock-knee length
- Hip breadth sitting
- Biacromial breadth
- Bideltoid breadth
- Functional reach
- Span
- Waist depth
- Thigh circumference

After being measured, the subject dressed in summer flying clothing and sat in the front seat, with the seat in its lowest position. After strapping in, the subjects were instructed to raise their seat until the top of the EADI's yellow triangle was just visible (uppermost point in Figure 2); the seat position was then recorded. This was considered to be the maximum allowable seat position from an EADI visibility standpoint. When unable to lower the seat sufficiently to see the top of the triangle, the distance between the top of the display and the highest visible point was measured as per Figure 3.

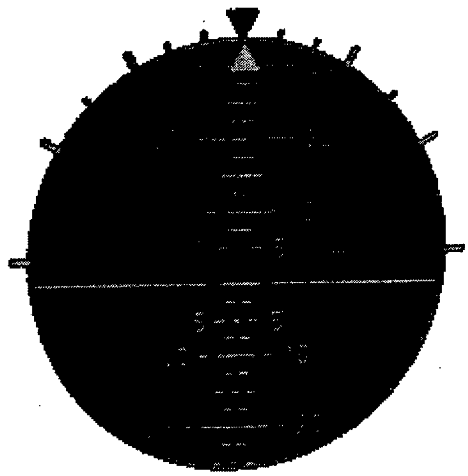

Figure 2. EADI.

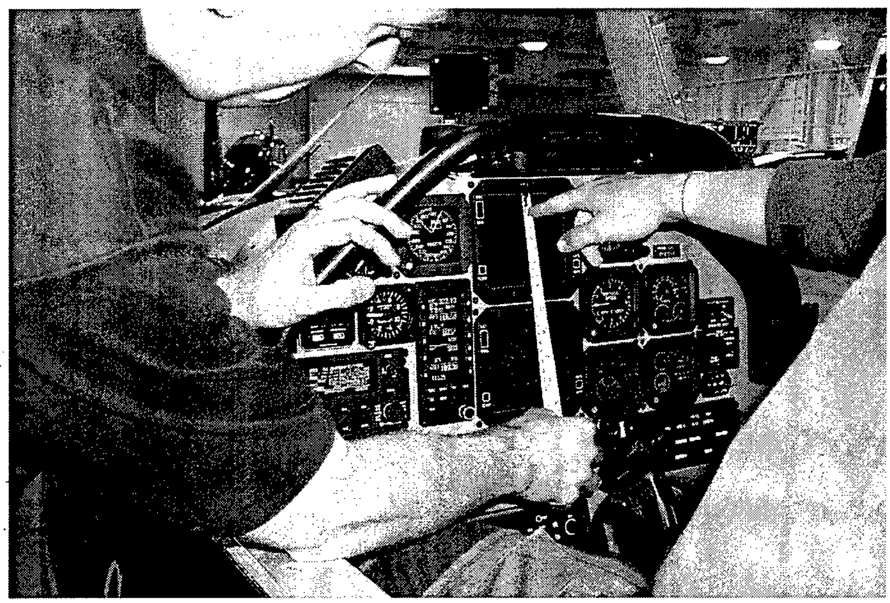

Figure 3. Measurement of the EADI visibility.

The rudder pedals were then adjusted as far forward as possible while still allowing the subject to have full throw of pedals and brakes; a laser scan of the pilot was then taken so as to capture

the three-dimensional posture of the subject for future modelling purposes. Aft left and aft right stick authority were then assessed first with one-handed operation, then allowing the subject to use both hands to maximize the range of motion. The maximum stick deflection position was recorded for both methods.

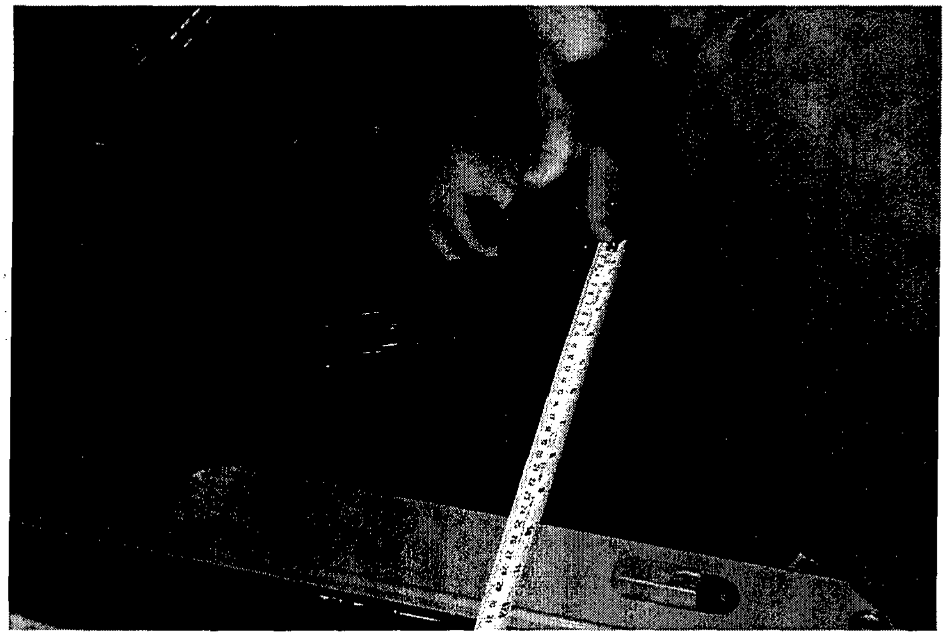

Figure 4. Measurement of stick range of motion (one-handed operation shown).

The subjects were then asked to raise their seat until there was just enough space between their helmet and the closed canopy to fit their fist. This method of positioning the seat achieves the highest position while ensuring that the canopy breakers are first to strike the canopy upon ejection. The seat position was recorded along with maximum aft left and right stick travel. The entire protocol was repeated in winter clothing and in the rear seat.

2.3 Seat pack

Figure 5 shows the LTS seat configuration as tested next to the original one. Both seats are shown upside down to enable comparison of their thickness. The physical changes of interest were as follows, based on Jonas, 2002):

- The aft edge of the sitting platform was raised by 50 mm (2.0 inches) and the forward edge raised by 38 mm (1.5 inches). The 'depressions' in the sitting platform were recontoured effectively raising the seat by 12 mm (½ inch) to create additional volume for the kit;

- The foam insert in the seat cushion was reduced in thickness by half to 12 mm (0.5 inches);

- The seat back was raised by approximately 50 mm (approximately 2 inches) and the upper edge was given a rolled edge;

- The seat raising actuator was restricted in travel by 50 mm (2.0 inches), reducing the uppermost travel of the seat.

For the purposes of this study, the seat raising actuator was modified for the front seat only, providing a positive seat full-up stop. The top of the rear seat travel was determined by placing the modified seat in the rear cockpit and marking the ejection rail with a grease pencil. The modified seat was returned to the front cockpit afterwards. The total seat travel was 130 mm.

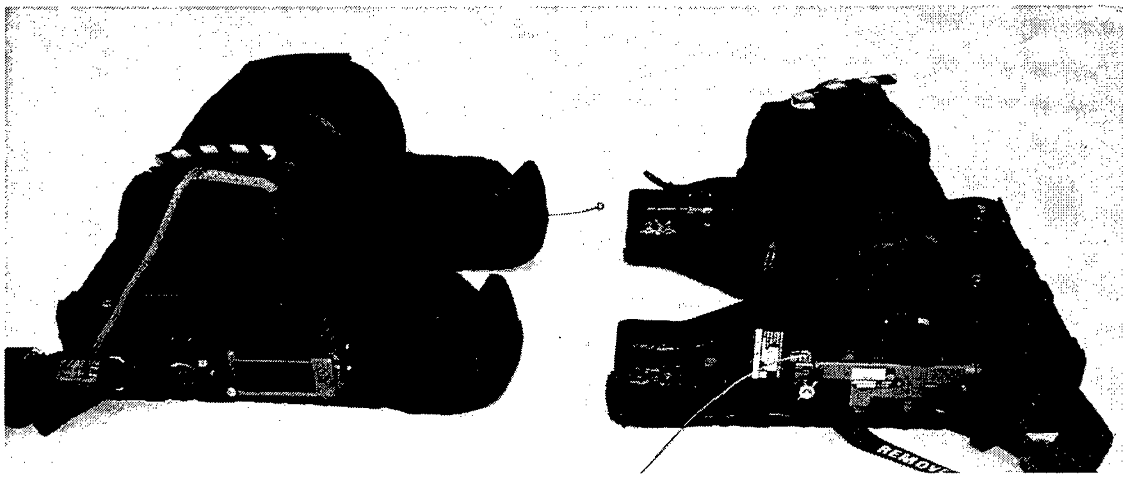

Figure 5. LTS seat (left) versus original seat.

3. Results and discussion

3.1 EADI visibility

Figure 6 and Figure 7 show the seat positions required by each test subject to achieve 100% visibility of the EADI. Figure 6 shows the effect of clothing on seat adjustment height, while Figure 7 shows the difference between front and rear cockpits.

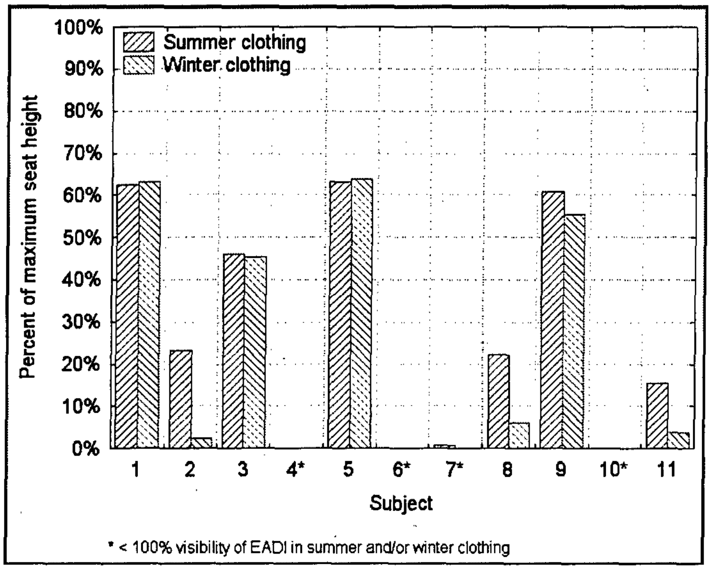

Figure 6. Seat position achieved for 100% visibility of the EADI for subjects in the front seat.

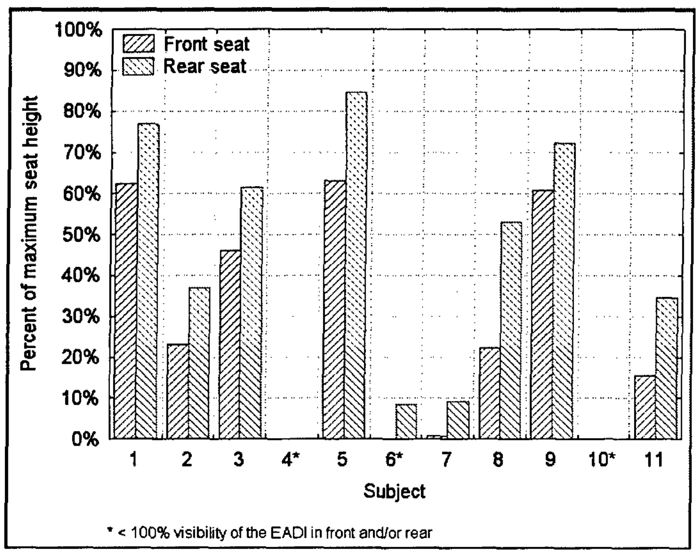

Figure 7. Seat position achieved in front versus rear seats for 100% visibility of the EADI (summer clothing).

It is apparent from these Figure 7 that the front seat is the more restrictive of the two because individuals need to sit lower in the cockpit, and will therefore have the largest impact on accommodation. It is interesting to note that four of the eleven subjects were unable to find a seat position where they could see the top of the yellow triangle from the front seat in winter clothing.

In order to obtain an estimate of the maximum Seated Eye Height that still enables 100% visibility of the EADI, the seat positions were added to the Eye Height Sitting measurement of the individuals. The term "effective" Eye Height Sitting is used to indicate that this value was

obtained by adding seat height to eye height sitting for all of the subjects who were able to see the top of the EADI's yellow triangle. Figure 8 shows the means (central dot), standard error of the means (box), and standard deviations (whiskers) for summer and winter clothing and for front and rear seats. The results confirm the effect of winter clothing on effective eye height sitting (of about 10 mm), as well as the considerable difference between the front and rear seats. These two observations are consistent with those of the original Harvard II accommodation study (Meunier, 2001).

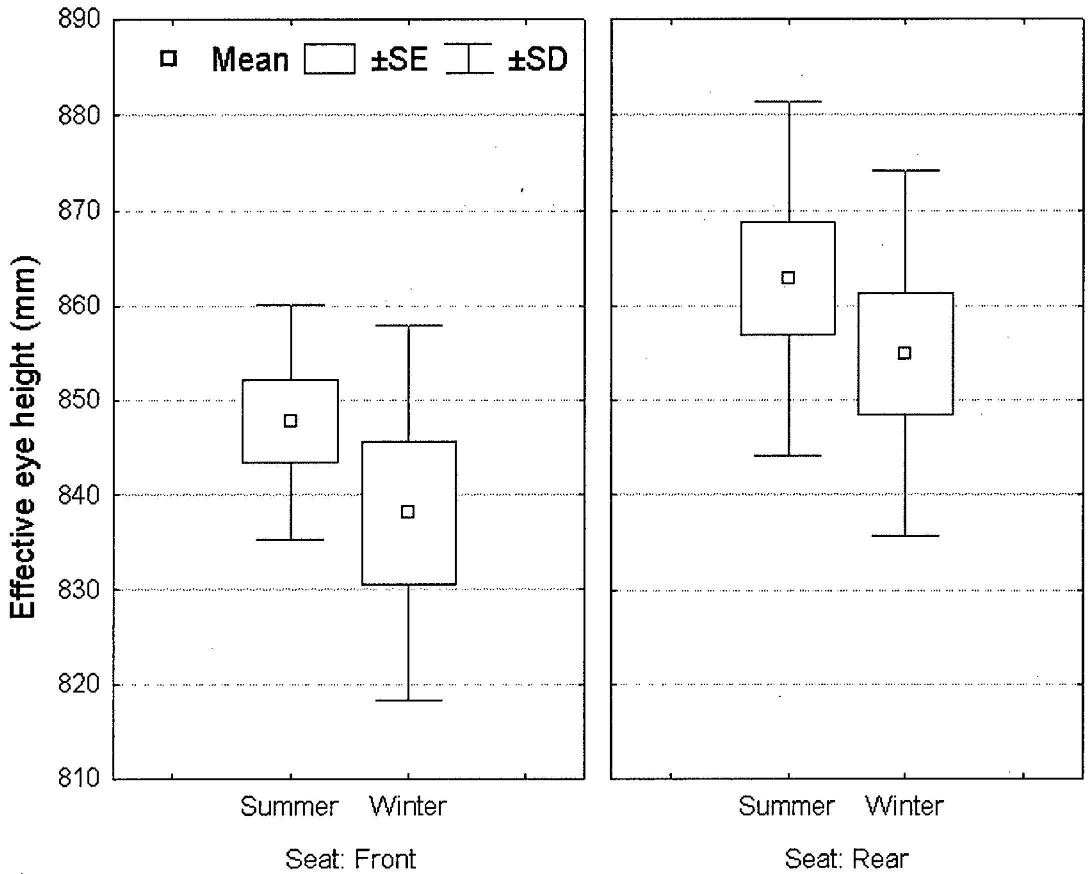

Figure 8. Effective Eye Height Sitting for front and rear cockpits.

Using the mean effective Eye Height Sitting as a criterion, the percentage of students that could not see the top of the yellow triangle of the EADI with the seat at its lowest position is estimated to be 12 percent to 17 percent of the students (i.e. front seat). This estimate is based on anthropometric data from the 1985 survey of aircrew (Stewart, 1985). Table 1 summarizes the anticipated effect of the seat modification for all seat and clothing conditions, while Figure 9 gives a pictorial representation of the summer and winter clothing cut-off values relative to a cumulative distribution of Eye Height Sitting from the 1985 survey of pilots. The bars of the histogram represent the actual distribution while the line represents the theoretical (normal) distribution.

Table 1 Effective eye height means and standard deviations (mm)

	Valid N	mean	S.D.	% affected
Front seat, summer	8	848	12	12%
Front seat, winter	7	838	20	17%
Rear seat, summer	10	863	19	6%
Rear seat, winter	9	855	19	8%

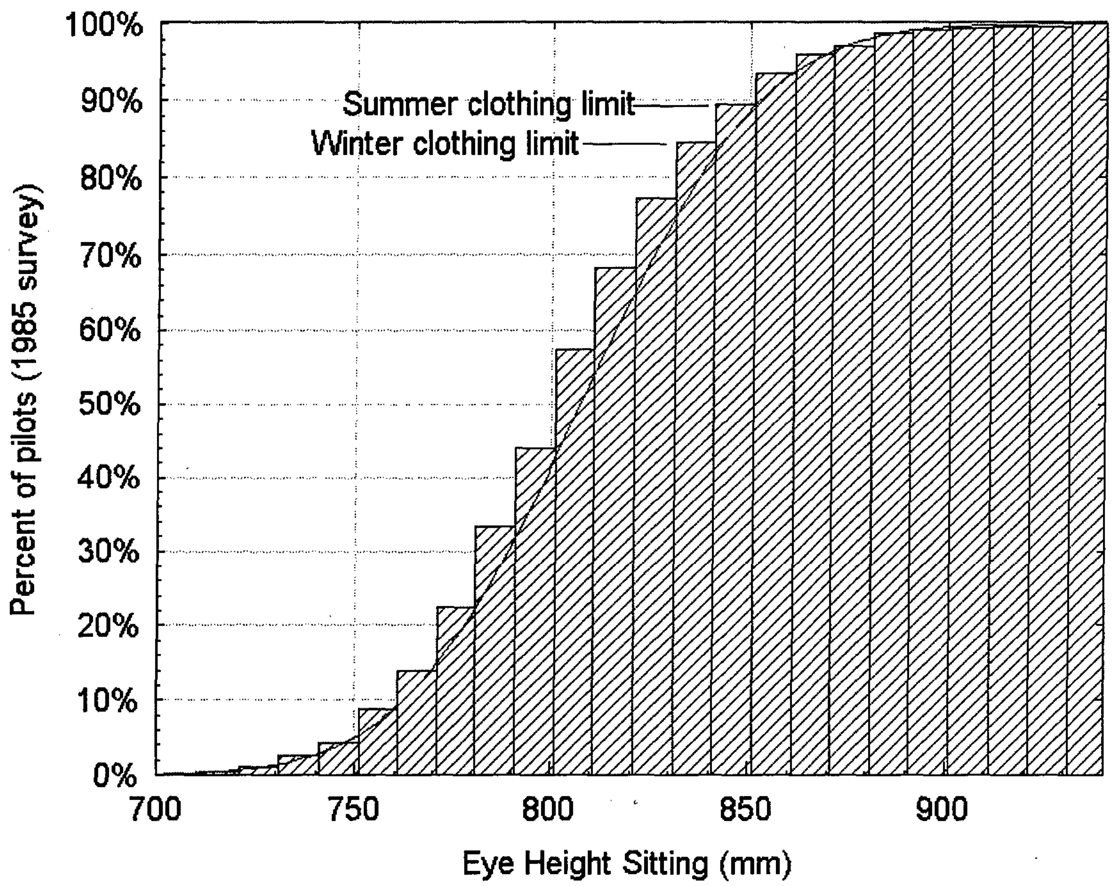

Figure 9. Eye Height Sitting distribution of 1985 population of pilots.

3.2 Maximum sitting height

Although visibility of the EADI is more limiting than helmet clearance, the increase in seat thickness can also reduce the clearance between the helmet and the canopy and put pilots at risk of not being protected by the canopy breakers upon ejection. The rule of thumb calls for the pilots to leave a space the size of the thickness of the fist between the helmet and the canopy (Jonas, 2002). Using the same approach as was used for effective Eye Height Sitting,

the seat position obtained when subjects were able to place their fist between the canopy and their helmet was added to their Sitting Height. The results, illustrated in Figure 10, show that the seat modification would put the limit at, or slightly below, the current aircrew selection maximum. An estimated 2% to 3% of pilots may encroach on the safety zone between the helmet and the canopy.

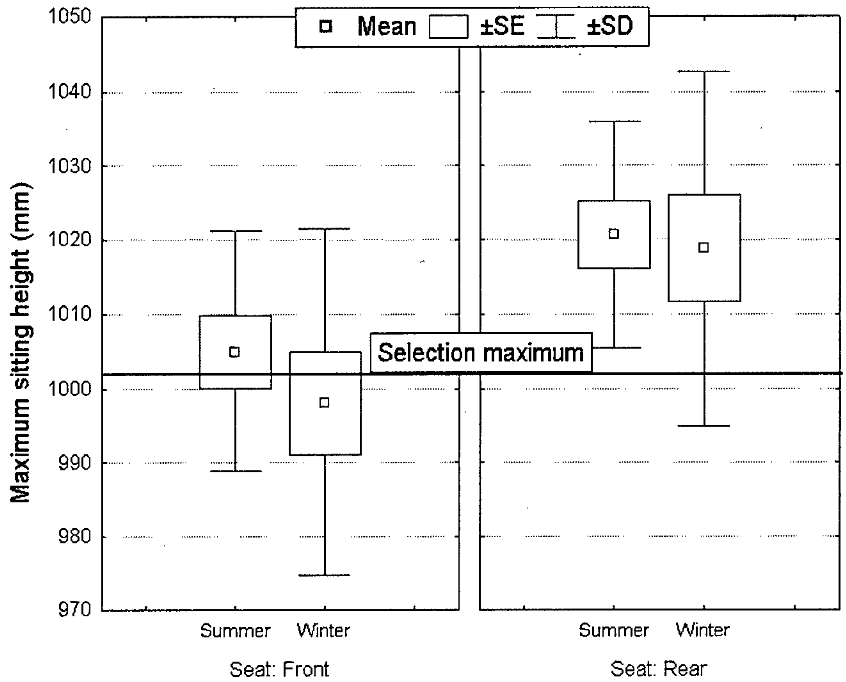

Figure 10 Maximum Sitting Height for front and rear cockpits.

3.3 Stick range of motion

Aft left and aft right stick range of motion were measured to determine the extent to which a higher seat position would affect them. A qualitative assessment was made by Adams, 2001) that the ability for the aircrew to achieve full aft control stick authority had been degraded by the increase in seat height.

A multiple regression analysis was performed on the raw data, the results of which are given in Tables 2 to 6. Seat position, mass (as a descriptor of body volume), and knee length or buttock-knee length (as an indication of leg length) were significant predictors of aft stick range of motion in summer clothing. It is apparent from the regressors that a higher seat positions decreases stick authority. This finding is consistent with the baseline study (Meunier, 2001). It also apparent from the Coefficients of Determination, R^2, of the regressions, that the results were more consistent in summer clothing than in winter clothing. The standard error of the estimates was around ± 5% for summer clothing, and in the neighbourhood of ± 10% for winter clothing. In other words, stick range of motion was predicted within 5% of the actual value in summer clothing and within 10% in winter clothing.

Table 2 Regression summary, summer clothing, stick aft left

R= .955 R^2= .912 Adjusted R^2= .893 F(3,14)=48.350
p<.00001 Std.Error of estimate: 5%

	Beta	Std.Err.	B	Std.Err.	t(14)	p-level
Intercept			0.04694	0.24430	0.19	0.850
Mass	-0.89	0.12	-0.00834	0.00110	-7.58	0.001
Knee Height Sitting	0.80	0.13	0.00285	0.00046	6.20	0.001
Seat Position	-0.71	0.12	-0.00288	0.00047	-6.15	0.001

Table 3 Regression summary, summer clothing, stick aft right

R= .899 R^2= .808 Adjusted R^2= .775 F(3,17)=23.918
p<.00001 Std.Error of estimate: 5%

	Beta	Std.Err.	B	Std.Err.	t(17)	p-level
Intercept			-0.1493	0.2508	-0.60	0.560
Mass	-1.20	0.22	-0.0074	0.0013	-5.53	0.001
Buttock-knee length	1.06	0.19	0.0029	0.0005	5.54	0.001
Seat Position	-0.86	0.14	-0.0022	0.0004	-6.00	0.001

Table 4 Regression summary, winter clothing, stick aft left

R= .879 R^2= .773 Adjusted R^2= .720 F(4,17)=14.478
p<.00003 Std.Error of estimate: 12%

	Beta	Std.Err.	B	Std.Err.	t(17)	p-level
Intercept			-1.750	0.6751	-2.59	0.019
Mass	-2.06	0.38	-0.030	0.0055	-5.40	0.001
Knee height sitting	1.19	0.24	0.006	0.0013	4.98	0.001
Waist Depth	1.18	0.26	0.006	0.0014	4.55	0.001
Seat position	-0.72	0.21	-0.004	0.0012	-3.35	0.004

Table 5 Regression summary, winter clothing, stick aft right

R= .839 R^2= .704 Adjusted R^2= .635 F(4,17)=10.134
p<.00022 Std.Error of estimate: 9%

	Beta	Std.Err.	B	Std.Err.	t(17)	p-level
Intercept			-1.269	0.518	-2.45	0.026
Knee height sitting	1.32	0.27	0.005	0.001	4.85	0.001
Mass	-2.24	0.43	-0.022	0.004	-5.15	0.001
Waist Depth	1.48	0.30	0.005	0.001	5.00	0.001
Seat position	-0.45	0.25	-0.002	0.001	-1.85	0.082

The regression equations were used to predict the range of stick motion of the 1985 population of pilots (Stewart, 1985). In order to simplify interpretation of the results, the aft left and right stick range of motion predictions were averaged.

Figure 11 shows the expected range of stick motion in summer and winter clothing for pilots sitting at the 100% EADI seat position. This is different from the original evaluation (Meunier, 2001) where the estimates were made in the lower, more favourable, Minimum Vision Over the Nose seat position[1]. As expected the percentage of pilots able to get full range of motion in summer clothing (defined as 90% to 100%) is slightly lower (49%) than it was in the original study (59%). However, the same percentage of pilots (~80%) is able to obtain approximately 80% to 100% stick range of motion in both studies.

In the case of winter clothing, it appears that the removal of the g-suit more than compensated for the rise in seat position. A much larger proportion of pilots are predicted to obtain 80% to 100% stick range of motion in this study compared to the original (54% versus 38%), and there are much fewer instances of individuals getting less than 60% of stick range of motion.

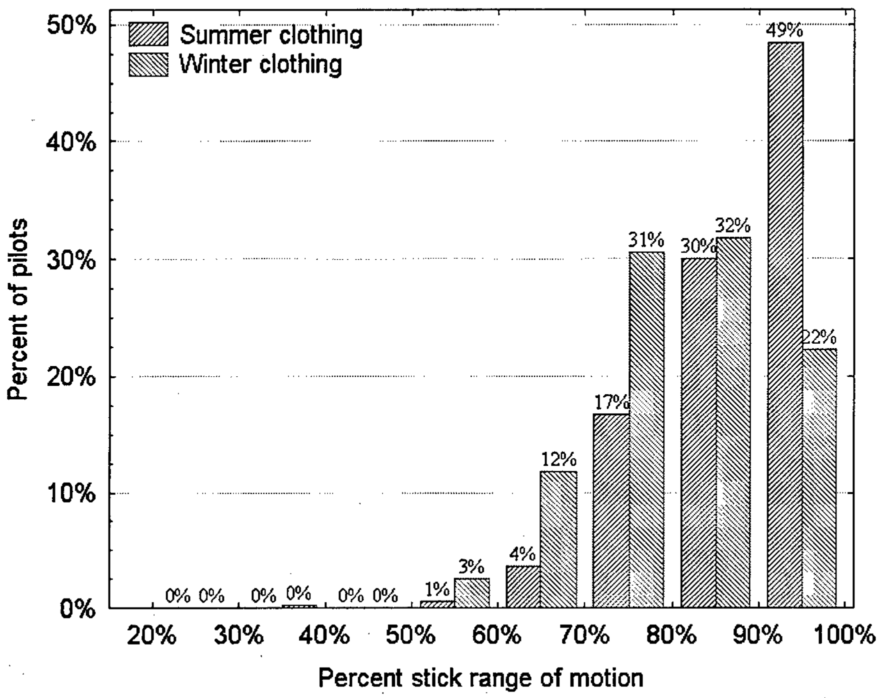

Figure 11 Predicted aft left and right stick range of motion in summer and winter clothing.

3.4 Other considerations

Another consideration that is brought about by sitting at the eye reference point is the Powered Inertia Retraction Device (PIRD) shoulder strap angle relative to the seat. The result of tests performed by AETE (Duggan, 2002) show that approximately 40% of student pilots would

[1] It should be noted that this more favourable condition was offset somewhat by extra bulk of the g-suit.

achieve an undesirable inertial restraint harness angle with the LTS seat. This could potentially put extra load on the spine during crash-landing or ejection. This situation should be examined more closely since this figure does not include instructors, who have a tendency to sit higher than the eye reference point. In practice, it is expected that a much larger percentage of instructors fly with a negative restraint harness angle.

4. Conclusions

The findings of this study can be summarized as follows:

1. The LTS seat pack will cause the taller 12% or 17% of student pilots (i.e. front seat) to sit higher than the reference eye point depending on whether they are flying in summer or winter clothing.

2. Although a technical solution to the EADI visibility problem may be devised, i.e. by relocating the enunciator panel, this may allow individuals to sit much higher than the reference eye point and bring pilots closer to the maximum sitting height limit. The maximum sitting height limit would nearly coincide with the current CF aircrew selection maximum. An estimated that 2% to 3% of pilots may exceed this limit and therefore have insufficient clearance between the top of their helmet and the canopy.

3. Stick authority does not appear to be affected much by operating the aircraft at the eye reference point rather than the lower "minimum over the nose" seat position. However, the data showed significant improvement from the removal of the g-suit from the winter clothing attire.

5. References

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Annex A Data collection sheet

Subject's name:________________________ M / F Date: ________________________

Location: ________________________

Age:	
Mass (kg):	
Stature:	
Thigh circumference:	
Thumbtip reach:	
Span:	
Sitting height:	
Eye height sitting:	
Acromial height sitting:	
Knee height sitting:	
Biacromial height:	
Bideltoid breadth:	
Hip breadth:	
Waist Depth:	
Buttock-knee length:	

Comments:

				Seat at 100% EADI				*Maximum seat height*			
Clothing	*Seat*	*EADI vis. (mm)*	*Seat Pos (cm)*	*Stick AL1 (cm)*	*Stick AR1 (cm)*	*Stick AL2 (cm)*	*Stick AR2 (cm)*	*Stick AL3 (cm)*	*Stick AR3 (cm)*	*Stick AL4 (cm)*	*Stick AR4 (cm)*
Summer	Front										
	Rear										
Winter	Front										
	Rear										

Annex B Anthropometric data

***Table 6** Anthropometric measurements of subjects (mm)*

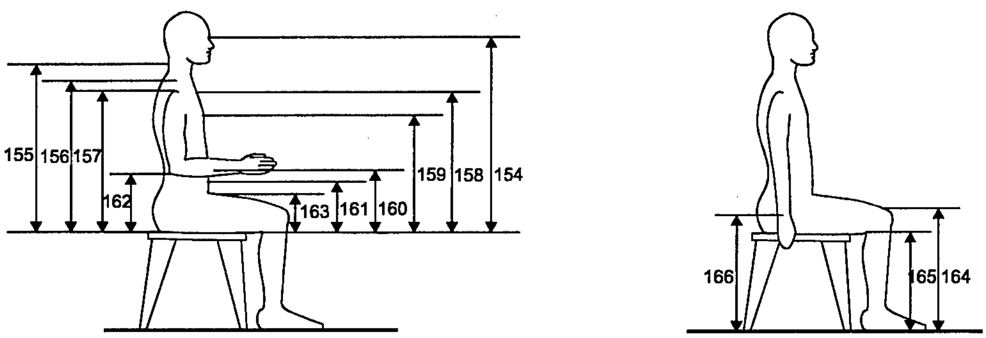
Subject	1	2	3	4	5	6	7	8	9	10	11
Height	1693	1912	1739	1935	1646	1933	1862	1739	1684	1815	1828
Mass (kg)	77	97.7	56.8	97.7	65	107	91.8	90.9	84	97.7	71
Span	1754	1985	1725	1932	1672	2050	1897	1701	1726	1822	1889
Sitting height	881	955	913	1016	885	963	970	916	883	952	954
Eye height sitting	772	830	783	897	782	836	845	794	767	823	827
Acromial height sitting	582	618	575	659	603	626	667	614	612	640	590
Knee height sitting	539	635	544	591	507	639	589	537	529	575	569
Buttock-knee length	616	666	585	665	552	674	629	634	618	605	605
Bideltoid breadth	494	534	427	510	468	574	519	490	536	556	484
Biacromial height	435	443	394	433	390	483	409	393	411	428	421
Hip breadth	380	396	377	395	304	410	384	404	402	399	344
Waist Depth	265	234	163	242	194	298	270	296	279	266	212
Thumb tip reach	742	799	694	817	732	823	805	728	735	742	838
Thigh circumference	642	615	553	622	570	617	616	705	636	674	540

***Table 7** Anthropometric measurements of subjects (%ile)*

Subject	1	2	3	4	5	6	7	8	9	10	11
Height	13.1	98.1	33.2	99.3	3.4	99.3	91.8	33.2	10.5	75.6	81.3
Mass (kg)	43.0	96.1	1.9	96.1	9.7	99.6	88.7	87.0	68.4	96.1	23.0
Span	17.9	97.7	10.0	90.8	2.5	99.8	81.2	5.6	10.2	47.6	78.4
Sitting height	11.0	81.7	38.1	99.6	13.4	87.2	90.9	41.4	12.2	79.4	81.0
Eye height sitting	15.7	74.5	24.5	99.5	23.6	79.7	86.2	35.4	12.5	67.6	71.6
Acromial height sitting	21.0	67.1	14.7	96.9	46.9	76.4	98.4	61.9	59.2	88.6	29.8
Knee height sitting	15.3	99.6	20.3	83.9	1.2	99.8	81.9	13.5	7.9	64.4	55.5
Buttock-knee length	59.4	97.8	19.3	97.6	2.1	98.9	75.8	81.0	62.1	43.9	43.9
Bideltoid breadth	65.6	98.6	0.5	86.8	22.2	99.9	93.6	58.8	98.9	99.9	48.1
Biacromial height	97.0	99.0	30.0	96.1	22.4	99.9	63.8	28.0	68.1	92.9	85.5
Hip breadth	65.0	85.7	60.1	84.8	0.2	95.2	71.1	92.1	90.7	88.4	12.4
Waist Depth	92.3	70.6	6.9	78.0	27.4	99.1	94.2	99.0	96.6	92.7	46.6
Thumb tip reach	9.2	54.0	0.6	70.9	5.7	75.9	59.9	4.6	6.6	9.2	86.0
Thigh circumference	84.3	64.2	13.4	70.2	24.1	66.0	65.1	99.4	80.6	96.1	7.8

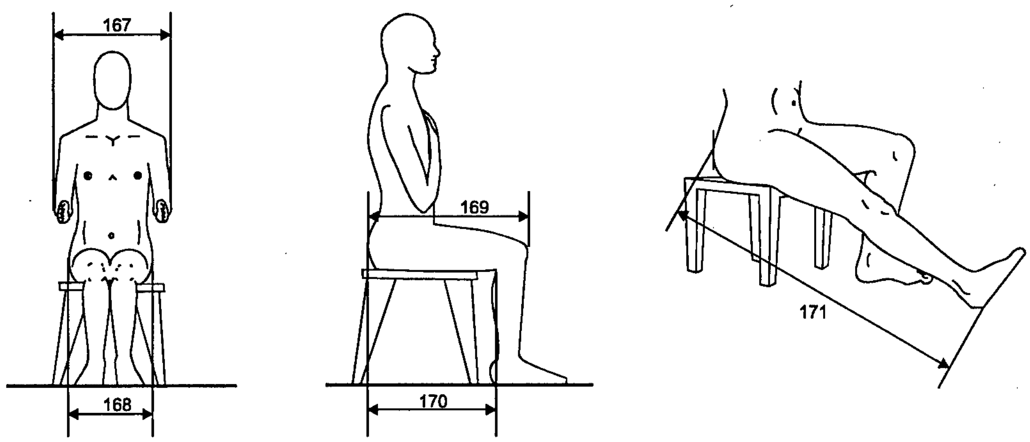
Definitions

The following are some of measurement definitions used in this study (taken from Chamberland et al., 1998).



154- Eye height sitting / Hauteur yeux assis
155- Cervicale height sitting / Hauteur cervicale assis
156- Midshoulder height sitting / Hauteur mi-épaule assis
157- Acromion height sitting / Hauteur acromion assis
158- Suprasternale height sitting / Hauteur supra-sternale assis
159- Chest height sitting / Hauteur thélion assis
160- Waist height sitting (nat.ind.) / Hauteur taille assis

161- Waist height sitting (omph.) / Hauteur omphalion assis
162- Elbow rest height / Hauteur coude assis
163- Thigh clearance / Hauteur encombrement cuisse
164- Knee height sitting / Hauteur genou assis
165- Popliteal height / Hauteur poplité
166- Wrist height sitting /Hauteur poignet assis



167- Forearm-forearm breadth / Largeur avant-bras - avant-bras
168- Hip breadth sitting / Largeur hanches assis
169- Buttock-knee length / Portée arrière genou assis

170- Buttock-popliteal length / Portée arrière creux poplité
171- Functional leg length / Longueur fesse-pied

Sitting Height (4)

The vertical distance between a sitting surface and the top of the head is measured with an anthropometer. The subject sits erect with the head in the Frankfort plane. The shoulders and upper arms are relaxed and the forearms and hands are extended forward horizontally with the palms facing each other. The thighs are parallel and the knees are flexed 90 degrees with the feet in line with the thighs. The measurement is made at the maximum point of quiet respiration.

Eye Height, Sitting (154)

The vertical distance between a sitting surface and the ectocanthus landmark on the outer comer of the right eye is measured with an anthropometer. The subject sits erect with the head in the Frankfort plane. The shoulders and upper arms are relaxed and the forearms and hands are extended forward horizontally with the palms facing each other. The thighs are parallel and the knees are flexed 90 degrees with the feet in line with the thighs. The measurement is taken at the maximum point of quiet respiration.

Acromial Height, Sitting (157)

The vertical distance between a sitting surface and the acromion landmark on the tip of the right shoulder is measured with an anthropometer. The subject sits erect looking straight ahead. The shoulders and upper arms are relaxed and the forearms and hands are extended forward horizontally with the palms facing each other. The measurement is made at the maximum point of quiet respiration.

Knee Height, Sitting (164)

The vertical distance between a footrest surface and the suprapatella landmark at the top of the right knee (located and drawn while the subject stands) is measured with an anthropometer. The subject sits with the thighs parallel, the knees flexed 90 degrees, and the feet in line with the thighs.

Buttock-Knee Length (169)

The horizontal distance between a buttock plate placed at the most posterior point on either buttock and the anterior point of the right knee is measured with an anthropometer. The subject sits erect. The thighs are parallel and the knees flexed 90 degrees with the feet in line with the thighs.

Functional Leg Length (171)

The straight-line distance between the plane of the bottom of the right foot with the leg extended and the back of the body of a seated subject is measured with an anthropometer passing over the trochanter landmark on the side of the hip. The subject sits erect on a stool 40.8 cm high. The right leg is extended and the foot is on the base plate of the anthropometer, which rests on the floor. The measurement is made from the footrest surface of the base plate.

Annex C Laser scanning consent form

Title: 3D posture acquisition using a laser scanner (Protocol L-343)
Principal Investigator: P Meunier, DRDC Toronto

I, ______________________________ (name, address, phone number) agree to be scanned as described in the attached protocol, which I have read. I have discussed the study with Pierre Meunier and I understand the objectives, procedures, risks, and benefits. All of my questions have been fully answered to my satisfaction. However, I may obtain additional information about the research project and have any questions about this study answered by contacting Pierre Meunier (416) 635-2093.

Concerning the principal risks of the study, I have been told that the laser being used in this study was not specifically designed for human scanning, but is of sufficiently low power (1 mW max average) to be considered eye safe. In spite of this, the investigator has elected to protect my eyes by having them closed and covered with an opaque sleep mask in order to completely eliminate any risk. I consider this to be acceptable. I acknowledge that my participation in this study may involve risks that are currently unforeseen by DRDC Toronto.

As a Canadian Forces member, I understand that I am considered to be on duty for disciplinary, administrative and Pension Act purposes during my participation in this experiment. This duty status has no effect on my right to withdraw from the experiment at any time I wish and I understand that no action will be taken against me for exercising this right. Furthermore, I understand that if my participation in this study results in a medical condition rendering me unfit for service, I may be released from the CF.

I understand that I am free to refuse to be scanned, without prejudice or hard feelings. I have been assured that any personal information concerning me that is revealed in connection with this study will be kept in strict confidence except as data unidentified as to the source.

Volunteer's Name: ______________________________
Signature: ____________________ Date: ____________________

Name of Witness to Signature: ______________________________
Signature: ____________________ Date ____________________

Principal Investigator: P. Meunier Signature:____________________ Date: __________

FOR SUBJECT ENQUIRY IF REQUIRED:

Should I have any questions or concern regarding this project **before, during, or after** participation, I understand that I am encouraged to contact the Defence R&D Canada - Toronto (DRDC Toronto), P.O. Box 2000, 1133 Sheppard Avenue West, Toronto, Ontario M3M 3B9. This contact can be made by surface mail at this address or in person, by phone or e-mail, to any of the DRDC Toronto numbers and addresses listed below:

- Principal Investigator or Principal DRDC TORONTO Investigator: Pierre Meunier (416) 635-2093, pierre.meunier@drdc-rddc.gc.ca

- Chair, DCIEM Human Research Ethics Committee (HREC): Dr Jack Landolt (416) 635-2120, jack.landolt@drdc-rddc.gc.ca

I understand that I will be given a copy of this consent form so that I may contact any of the above-mentioned individuals at some time in the future should that be required.

Annex D CF aircrew selection limits

Table 8 Current pilot selection limits (mm).

	Stature	Sitting height	Buttock-knee length	Functional leg length
Minimum	1570	864	546	996
Maximum	1940	1003	673	1232

List of symbols/abbreviations/acronyms/initialisms

AETE	Aerospace Engineering Test Establishment
CATP	Canadian Aerospace Training Project
CMB	Central Medical Board
DND	Department of National Defence
DTA	Directorate of Technical Airworthiness
EADI	Electronic Attitude and Direction Indicator
LTS	Long Term Solution
NFTC	NATO flying training in Canada
PIRD	Powered Inertia Retraction Device
SRP	Seat Reference Point
SSK	Seat Survival Kit (SSK)

Distribution list

CATP (Canadian Aerospace Training Program)

CAS Med Adv

DTA

D Med Pol

DAR

2 CFFTS

15 Wing WComd

CO AETE/DT&E

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4. AUTHORS Pierre Meunier

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14. ABSTRACT

(U) The requirement to include additional survival equipment as part of the seat survival kit of the Harvard II has caused a significant increase to the seat thickness (4 to 5 cm). A previous study determined that any increase in seat thickness would likely have repercussions on the ability of the taller individuals to see all of the information displayed by the Electronic Attitude Director Indicator (EADI), on control stick authority, and possibly on helmet to canopy clearance. The object of this study was to assess the impact of this new seat pack, or Long Term Solution (LTS) seat pack, on pilot accommodation. The study found that approximately 12% to 17% of student pilots (i.e. individuals in the front seat) would not be able to see all of the EADI information. In addition, the taller 2% to 3% of pilots would likely exceed the aircraft's maximum sitting height limits and have insufficient clearance between the top of the helmet and the canopy. Stick authority was relatively little affected by the proposed seat compared to the baseline. Removal of the g-suit from the winter clothing configuration significantly improved stick authority.

(U) L'obligation d'inclure du matériel de survie additionnel dans le nécessaire de survie du siège du Harvard II a entraîné une importante augmentation de l'épaisseur dudit siège (de 4 à 5 cm). Une précédente étude avait établi que toute augmentation de l'épaisseur du siège risquait d'avoir des répercussions sur la capacité des personnes de grande taille à voir l'intégralité de l'information affichée par l'indicateur-directeur d'assiette électronique (EADI), sur leur maîtrise du manche, voire même sur l'espacement qui sépare le casque de la verrière. La présente étude avait pour objet d'évaluer les répercussions que pouvait avoir ce nouveau paquetage de siège, appelé solution à long terme (LST), sur la posture du pilote. Cette étude a établi que de 12 à 17 % des élèves-pilotes (c'est-à-dire des personnes se trouvant sur le siège avant) ne pourraient pas voir l'intégralité de l'information affichée par l'EADI. De plus, les pilotes les plus grands (2 à 3 %) risquent fort de dépasser la hauteur assise maximale admise dans l'appareil et de ne pas jouir d'un espace suffisant entre le sommet du casque et la verrière. La maîtrise du manche s'est révélée être relativement peu affectée par le remplacement du siège d'origine par le siège proposé. La suppression de la tenue anti-g de la tenue d'hiver a amélioré considérablement la maîtrise du manche.

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) Cockpit accommodation, Harvard II, anthropometry

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